



Linking GMES Space Component to the development of land policies in Outermost Regions – the Azores (Portugal) case-study

Artur Gil^{1*}, Catarina Fonseca², Agustín Lobo³ and Helena Calado²

¹Azorean Biodiversity Group, CITA-A, Department of Biology, University of the Azores, Campus Universitário de Ponta Delgada, Rua da Mãe de Deus 13A, 9501-801 - Ponta Delgada, Portugal

²CIBIO (Azores Unit), Department of Biology, University of the Azores, Campus Universitário de Ponta Delgada, Rua da Mãe de Deus 13A, 9501-801 - Ponta Delgada, Portugal

³ICTJA - Institut de Ciències de la Terra Jaume Almera (CSIC), E-08028 - Barcelona, Spain

*Corresponding author, e-mail address: arturgil@uac.pt

Abstract

The aim of this study is to assess the potential effectiveness of GMES Space Component Sentinel Missions for land-based environmental policy support in the Azores Autonomous Region (Portugal). Sixteen different types of legal and spatial instruments are currently being applied in this region. Most of them require detailed and accurate Land-use/Land-cover cartography in order to deliver reliable outputs at municipal, island and archipelagic scales. Sentinel-2 Mission products can fulfill these requirements in a cost-effective way. A Spatial Data Infrastructure-based Regional GMES framework is proposed in order to process, assess, validate and integrate this GMES data into the decision support system of Azorean regional land policies.

Keywords: GMES, Sentinel Missions, Outermost Regions, Azores, Land Policy, LULC Mapping.

Introduction

Small Islands and European Outermost Regions

The outermost regions listed in Article 349 of the Treaty on the Functioning of the European Union (EU) are: Guadeloupe, French Guiana, Martinique, Réunion (French *départements*), Saint-Barthélemy, Saint-Martin (French *collectivités d'Outre-mer*), the Azores, Madeira (Portuguese autonomous regions), and the Canary Islands (Spanish autonomous community). In 2006, almost 4.3 million people lived in the EU outermost regions, representing 0.9% of the EU population. These regions face several obstacles to full development – remoteness, insularity, terrain and climate constraints, economic dependence and narrow range of the

goods they produce. These realities constitute disadvantages for their sustainable and harmonious development and the EU, through various programmes and measures, aims to minimise them as much as possible in order to promote the economic and social convergence of these regions [Monfort, 2009]. The European Commission communication entitled “The outermost regions: an asset for Europe” [2008a], advocates an alternative approach, focusing on the potential contribution of these regions to overall growth and development in Europe. A strategic priority is to turn the handicaps of outermost regions into assets. For example, the outermost regions have geographical and geological characteristics that make them excellent laboratories for research in a number of fields including climate change, and have a unique geostrategic position. Also their biodiversity and exceptional marine ecosystems are very promising in specific fields like innovation in pharmaceuticals and agronomy.

It is worth noting that the majority of outermost regions – except the French Guiana – are small islands or archipelagos. Climate Variability and Changes, the proliferation of invasive exotic species, the increasing growth of tourist activity, natural catastrophes, the overexploitation of natural resources as well as the pollution and residue management are the main threats to sustainable development, to nature conservation and to small island biodiversity maintainability [CBD, 2006]. These characteristics, associated with remoteness, isolation, smallness, and particularly closed systems, make Planning and Management on small islands more challenging in scientific and technical terms [Calado et al., 2007]. Despite its usefulness at European continental and regional level, Pan-European mapping projects created and developed to address environmental issues, like Corine Land Cover (CLC), the European Environment Agency program for land-use/land-cover (LULC) multi-temporal mapping and assessment in Europe, have been ineffective to address and characterize Outermost Regions LULC issues, due to its inadequate geographic scale, spatial resolution and category classification. For instance, the Azores Islands were not covered by CLC 1990, 2000 and 2006 campaigns.

The Archipelago of the Azores: an Autonomous Portuguese Region

The Portuguese Constitution of 1976 (Articles 227 and 228, Title VII) confirmed the autonomous region of the Azores as an authentic political region with an autonomy that implied the exercise of their own legislative and executive powers, as well as the administrative and financial ones. The bodies of government for the regions are: the regional assembly – elected by direct universal suffrage – and the regional government. The decrees which approved the statutes of autonomy were passed on April 30th 1976. The first regional elections took place on June 27th of the same year. According to the Constitution, the political and administrative organization of the archipelago is based on its geographic, economic, social and natural characteristics, as well as the historical aspirations for autonomy of the islands’ populations. The most important differentiating factor that justifies a separate political and administrative system for the Azores is based on its geographical peculiarities, i.e. the nature of its insularity [Suárez de Vivero, 1995]. The Azores Autonomous Region (Fig. 1) consists of an archipelago of nine islands of volcanic origin located between 37 to 40° N and 25 to 31°W. Due to geographical distribution, they are divided into three groups: the Western Group (Flores and Corvo), the Central Group (Pico, Faial, São Jorge, Graciosa and Terceira) and the Eastern Group (São Miguel and Santa Maria). They occupy an area of 2,333 km² and have a population of circa 240,000

inhabitants. The largest island is São Miguel (745 km²), and the smallest is Corvo (17 km²). Santa Maria is the southern- and easternmost island (37° N, 25° W), Flores is the westernmost (31° W), and Corvo (39°42' N) is the northernmost island. Pico has the highest elevation point (2351 m above sea level). Five other islands have elevations of nearly 1000 m above sea level. The three island groups are separated by 1000–2000-m-deep sea channels, except the islands of Faial and Pico, between which the channel is, in many parts, only 20 to 50 m deep. The Azores are separated from the most western point of mainland Europe (i.e., Cabo da Roca, Portugal) by 1390 km. Located in the Atlantic Ocean at a mean latitude of 38°30' N, the Azores enjoy a distinctly oceanic climate. Despite its small land area, the Azores archipelago has an Exclusive Economic Zone (EEZ) of approximately 940,000 km². The islands are geologically young and are located in a tectonically and volcanically active region, distributed over a 600 km approximately WNW-ESE strip. They emerge from the Azores plateau, a triangular-shaped zone of anomalous and irregular shallow topography and tectonically located near the triple junction of the American (west), Eurasian (northeast) and African (south) plates. The insignificant variation in the seasonal temperature and the high humidity and precipitation that characterize the archipelago's climate are mostly due to the influence of the Gulf Stream, which transports warm waters and humid air masses and is responsible for the high-pressure systems over the Azores [Borges et al., 2009; Calado et al., 2011].

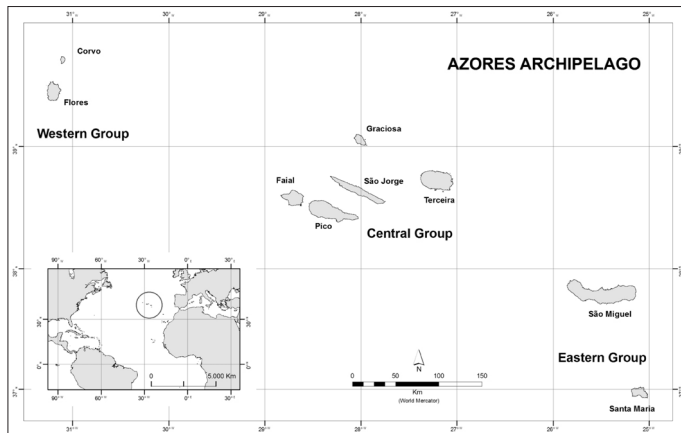


Figure 1 – Location of the Archipelago of the Azores.

Remote Sensing for Environmental Policy Support

The diversity of technology and infrastructures to monitor environmental systems, from global to local scales, is increasing rapidly, as public and private organizations increase their investment in them. These data and images support policies by contributing to the development and improvement of new policies, as new problems can be discovered or visually better conveyed to the public. Policy implementation and evaluation requires data to ensure compliance and to monitor the policy's success. The various phases of an environmental policy require up-to-date and synoptic spatial information at various spatial scales on the state of the environment and the extent and magnitude of environmental and

policy impacts over large areas. Earth observation (EO) is well suited for this, as a large number of variables relevant to environmental policy can be remotely detected. Moreover, remote sensing (RS) permits repeated and consistent assessment and monitoring of the environment; it allows independent control and its quality can be assessed. Therefore it is a tool with some very desirable characteristics for supporting environmental policy [Esty, 2004; Backhaus and Beule, 2005; De Leeuw, 2010]. There is a growing interest in the application of remote sensing technologies to the protection of global environment. Remote Sensing data has many attractive features in the context of environmental instruments. It is generally accurate and objective; it can have globally-consistent coverage; it can be tuned to ecological regions of widely-varying scales; and because it is sensed from space, it can present a wide range of relevant data synoptically and without infringing national sovereignty. While international or collaborative monitoring of the environment is not currently central to most environmental policies, to the extent that monitoring takes place; remote sensing is a promising method [Uhlir, 1995; Kline and Raustiala, 2000; De Sherbinin 2002]. Environmental protection and regulatory enforcement are particularly likely to benefit from new enforcement technologies such as Remote Sensing, since its attributes include: the quantity and quality of the information supplied by the new technologies; the accessibility of the information to regulators, regulatees, and third parties; the cost of the information; and whether the process of information gathering can be concealed from the observer. RS technologies are likely to influence all of these attributes and, in general, improve the efficacy of enforcement. A systematic insight in, and awareness of, how remote sensing may contribute to environmental policy can help to enlarge the societal demand for EO applications. However, existing reviews of environmental EO applications are structured according to products, techniques, or benefit areas, rather than the function they have, with respect to the policy they support. [Macauley and Brennan, 1998; De Leeuw, 2010; Purdy, 2010]. Reid et al. [2010] issued a call to explicitly link research on global environmental change with sustainable development. This would encompass the use of remote sensing not only for monitoring environmental conditions, but also to measure the feedbacks between these conditions and human activity and governance. Remote sensing data could be incorporated into large, complex models of socioeconomic systems (to help determine the social and economic impacts of environmental changes), and existing efforts (such as GEOSS) could be modified to include an assurance that its products would meet the needs of decision-makers and are scaled appropriately for sustainable development policy [Mayer and Lopez, 2011].

The Global Monitoring for Environment and Security initiative

In 2005, the EU made the strategic choice of developing an independent European Earth Observation capacity called Global Monitoring for Environment and Security (GMES) in order to deliver services in the environmental and security fields. GMES consists of the following three components: (1) Space Component – consists of a space observation infrastructure addressing service data needs with the missions of observing land, atmospheric and oceanographic parameters; (2) In-Situ Component – will rely on a large number of facilities, instruments and services owned and operated at national, regional and intergovernmental levels inside and outside the EU; (3) GMES Services – the basis for Europe's autonomy in information provision world-wide. Since 2008, four preoperational

GMES services have been launched: a land monitoring service, a marine service, an atmospheric composition monitoring service and an emergency response service. GMES is also at the heart of the EU contribution to the Global Earth Observation System of Systems (GEOSS) [European Commission, 2008b, 2009].

The GMES Space Component

The GMES Space Component comprises 6 series of Earth observation Sentinel missions. Some 12 missions, split into six constellations, are currently under development. The Sentinel series comprise constellations of a number of 5 units (Tab. 1). This is the answer to the user requirements for the implementation of GMES services which expressed the need for observation continuity and seamless access to data, redundancy in the context of an operational system and increased frequency of observations [Aschbacher et al., 2010].

Table 1 – ESA's Sentinel Missions overview [Aguirre et al., 2007; Attema et al., 2007; ESA, 2007; Martimort et al., 2007].

Mission	Mission Objectives	Main Features	Core Applications	Launch & Lifetime
Sentinel 1	European polar orbiting radar observatory providing continuity of SAR data for operational applications	C-Band SAR (Centre frequency: 5.405 GHz; Polarization: VV+VH,HH+HV; Incidence angle: 20° - 45°; Radiometric accuracy: 1 dB (3 σ); NESZ: -22 dB; DTAR: -22 dB; PTAR: -25 dB); Four nominal operational modes designed for inter-operability with other systems: (1) Strip Map Mode with 80 km swath and 5x5 m spatial resolution; (2) Interferometric Wide-Swath Mode with 250 km swath, 5x20 m spatial resolution and burst synchronization for interferometry; (3) Extra-Wide-Swath Mode with 400 km swath and 20x40 m spatial resolution; (4) Wave Mode with 5x5 m spatial resolution leap-frog sampled images of 20x20 km at 100 km along the orbit, with alternating 23° and 36.5° incidence angles.	Monitoring sea ice zones and the arctic environment; surveillance of marine environment; monitoring land surface motion risks; mapping of land surfaces: forest, water and soil, agriculture; mapping in support of humanitarian aid in crisis situations	S1-A Launch: 2013; S1-B Launch: 2015; 7 years lifetime (consumables for 12 years)
Sentinel 2	Wide-swath high-resolution twin satellites super-spectral imaging mission designed for data continuity and enhancement of Landsat and SPOT-type missions	13 spectral bands: 443 nm– 2190 nm (spectral resolution: 15 nm– 180 nm); Spatial resolution: 10m, 20m and 60m; Swath: 290 km; Radiometric resolution/ accuracy: 12 bit / < 5%; Global revisit time: 5 days with 2 satellites flying concurrently (2 to 3 days in extended mode)	Land cover, usage and change-detection-maps; geophysical variable maps; fast images for disaster relief	Launch: 2013; 7 years lifetime (consumables for 12 years)

Table 1 – (Continued) ESA's Sentinel Missions overview [Aguirre et al., 2007; Attema et al., 2007; ESA, 2007; Martimort et al., 2007].

Mission	Mission Objectives	Main Features	Core Applications	Launch & Lifetime
Sentinel 3	European global land and ocean monitoring mission	<p>* OLCI (Ocean & Land Colour Instrument): Swath width of 1270 km; 5 tilted cameras; Spatial sampling of 300m; Spectrum with 21 bands [0.4-1.02] μm; Radiometric accuracy of 2% abs, 0.1% rel.</p> <p>* SLSTR (Sea and Land Surface Temperature Radiometer): Swath width (dual view scan) of 1420 km (nadir) / 750 km (backwards); Spatial sampling of 500 m (VIS, SWIR), 1 km (MWIR, TIR); Noise equivalent dT of 50 mK (TIR) at 270K.</p> <p>* SRAL (Sentinel-3 Ku/C Radar Altimeter): Pulse repetition frequency of 1923.87 Hz; Radar measurement modes: LRM and SAR; Tracking modes: closed and open-loop; Total range error: 3 cm.</p> <p>* MWR (MicroWave Radiometer): dual 23.8/36.5 GHz; Radiometric accuracy of 3K absolute (0.6 K relative).</p> <p>*POD (Precise Orbit Determination): GPS, LRR and DORIS (3 cm final accuracy after processing).</p>	It provides 2 day global coverage Earth observation data (with 2 satellites) for sea and land applications with real-time products delivery in less than 3 hours: sea and land colour data in continuation of MERIS (Envisat); sea and land surface temperature in continuation of AATSR (Envisat); sea-surface and land-ice topography in continuation of Envisat altimetry; along-track SAR for coastal zones, in-land water and sea ice topography; vegetation products through synergy between optical instruments	Launch: 2013; 7 years lifetime (consumables for 12 years)
Sentinel 4	Continuous monitoring of the atmospheric chemistry at high temporal and spatial resolution from the geostationary orbit	The Sentinel-4 UVN instrument is a high resolution spectrometer covering the ultraviolet (305-400 nm), visible (400-500 nm), near-infrared (750-775 nm) bands. The spatial sampling is 8 km and a spectral resolution between 0.12 nm and 0.5 nm (depending on the band). Will be embarked on the Meteosat Third Generation Sounder satellite (MTGS). Coverage is achieved by scanning by a fast repeat cycle over Europe and North Africa (Sahara) of 60 minutes (goal 30 minutes).	The main data products will be O ₃ , NO ₂ , SO ₂ , HCHO and aerosol optical depth, which will be generated with high temporal resolution (~ 1 hour) to support air quality monitoring and forecast over Europe.	Launched with MTG-S1 and MTG-S2.

Table 1 – (Continued) ESA’s Sentinel Missions overview [Aguirre et al., 2007; Attema et al., 2007; ESA, 2007; Martimort et al., 2007].

Mission	Mission Objectives	Main Features	Core Applications	Launch & Lifetime
Sentinel 5 precursor	The Sentinel-5 precursor is a UV-VIS-NIR-SWIR spectrometer payload derived through tailoring of Sentinel-5 specifications.	UV-VIS-NIR-SWIR push-broom grating spectrometer; Number of Channels: 5; Spectral Range: 270-495 nm, 710-775 nm, 2314-2382 nm (spectral resolution: 0.25-1.1 nm); Observation Mode: Nadir, global daily coverage, ground pixel 7x7 km ² ; Radiometric Accuracy: ~ 2%	Sentinel-5 precursor will provide measurements of elements of atmospheric chemistry at high temporal and spatial resolution. It will increase the frequency of cloud free observations required for the study of troposphere variability. In particular this mission is expected to provide measurements of ozone, NO ₂ , SO ₂ , CO and aerosol.	Launch: 2014

Methods

The aim of this study is to assess the potential usefulness and importance of GMES Space Component’s Sentinel Missions to support land-based environmental policies developed by the European Outermost Regions (most of them being Small Islands), using the Archipelago of the Azores (an Autonomous Region of Portugal) as case-study. This methodological approach can be divided into three main phases:

- 1) Identification of land-based Azorean Regional legal instruments with environmental and spatial incidence, describing their legal framework, core subject(s) and domain(s), main goal(s) and geographic scope(s).
- 2) Linking land-based environmental and spatial legal instruments in the Azores Autonomous Region to EO products obtained from GMES Space Component Sentinel Missions.
- 3) Proposing a Spatial Data Infrastructure-based “GMES Azorean Regional Framework”, in order to maximize the societal benefits derived from the access to GMES Space Component Sentinel Mission outcomes.

Results and Discussion

The environment is assumed as a transverse pillar for all of the Region’s social and economic activities and sectors [Azorean Regional Government, 2008]. This assumption is confirmed by the quantity (16) and diversity of current legal land-based instruments with environmental and spatial incidence in the Azores, regulating and acting at the archipelagic, island and municipal scale (Tab. 2).

Municipal Master Plans (PMOT), at municipal level, and Special Land Management Plans

(PEOT), at basin, coastal zone and protected area levels, are the core instruments for land planning in the Azores because they are the only binding spatial plans where soil and land-use are effectively classified and regulated. To reach their goals, they must base their classification and land-use policies in compliance with several region-scaled and island-scaled thematic legal instruments covering two different core domains:

- Environmental Conservation and Biodiversity Protection: Regional Network of Protected Areas (RRAP); National Ecological Reserve's Legal Instrument (REN) for biophysical system integrity preservation; and Legal Instrument for Environmental Impact Assessment and Licensing (RJAIA);
- Natural Resources planning and management: Legal Instrument for Mineral Resources definition and exploration (RJRAMM); Regional Agricultural Reserve (RAR) for agricultural soils' protection; Legal Instrument for Agricultural Planning and Cadastre (RJOA); Legal Instrument for Forestry Resources Protection, Planning and Management (RJOF).

Table 2 – Land-based legal instruments with environmental and spatial incidence in the Azores Autonomous Region.

Legal Instrument	Regulatory Decree-Law (National or Azorean Autonomous Law)	Core Subject(s)	Main Goals	Geographic Scope
Azores Master Plan Scheme (PROTA – “Plano Regional de Ordenamento do Território da Região Autónoma dos Açores”)	Regional Decree-Law 26/2010/A	Land Management and Planning Regional Sustainable Development Natural Resources Planning and Management	Defines a Regional Strategy for Land Management based on geographical, socioeconomic and ecological criteria	Region (Archipelago) Island
Special Land Management Plans (PEOT – “Planos Especiais de Ordenamento do Território”)	Regional Decree-Law 14/2000/A	Land Management and Planning Environmental Conservation and Biodiversity Protection	Regulates the land planning and management in specific geographical features: basins and lagoons; Protected Areas; coastal zones	Basin and Lake Protected Area Coastal Zone
Municipal Master Plans (PMOT – “Planos Municipais de Ordenamento do Território”)	Regional Decree-Law 14/2000/A	Land Management and Planning	Regulates the land planning and management in municipalities	Municipality

Table 2 – (Continued) Land-based legal instruments with environmental and spatial incidence in the Azores Autonomous Region.

Legal Instrument	Regulatory Decree-Law (National or Azorean Autonomous Law)	Core Subject(s)	Main Goals	Geographic Scope
Regional Plan of Tourism (POTRAA – “Plano de Ordenamento Turístico da Região Autónoma dos Açores”)	Regional Decree-Law 38/2008/A	Land Management and Planning Tourism Planning and Management	Defines a Regional Strategy for Tourism Planning and Management based on geographical, socioeconomic and ecological criteria	Region (Achipelago) Island
Regional Network of Protected Areas (RRAP – “Rede Regional de Áreas Protegidas dos Açores”)	Regional Decree-Law 15/2007/A	Environmental Conservation and Biodiversity Protection	Defines the Protected Areas’ Planning and Management Units	Region (Achipelago) Island
Sectorial Plan for the Natura 2000 Network Management in the Azores Autonomous Region (PSRN2000 – “Plano Sectorial da Rede Natura 2000 para a Região Autónoma dos Açores”)	Regional Decree-Law 20/2006/A; Rectification Statement 48-A/2006; Regional Decree-Law 7/2007/A	Environmental Conservation and Biodiversity Protection	Defines a Regional Strategy for the Natura 2000 Network Management in the Azores Autonomous Region	Region (Achipelago) Island
Regional Plan for Invasive Alien Species Control in Sensitive Areas (PRECEFIAS – “Plano Regional de Erradicação e Controlo de Espécies de Flora Invasora em Áreas Sensíveis”)	Government Council Resolution 110/2004	Environmental Conservation and Biodiversity Protection	Identifies most critical sensitive areas and defines management measures for Invasive Alien Species Control in these sites	Region (Achipelago) Island
Legal Instrument for Mineral Resources definition and exploration (RJRAMM – “Regime Jurídico da Revelação e Aproveitamento de Massas Minerais na Região Autónoma dos Açores”)	Regional Decree-Law 12/2007/A	Natural Resources Planning and Management	Defines the legal instrument for an optimal Mineral Resources exploration with minimal environmental and socioeconomic impacts	Region (Achipelago) Island
Legal Instrument for Environmental Impact Assessment and Licensing (RJAIA – “Regime Jurídico de Avaliação do Impacte e Licenciamento Ambiental”)	Regional Decree-Law 30/2010/A	Environmental Conservation and Biodiversity Protection Natural Resources Planning and Management Regional Sustainable Development	Defines the legal instrument for Environmental Impact Assessment of projects and programmes and for Environmental Licensing of economic activities	Region (Achipelago) Island

Table 2 – (Continued) Land-based legal instruments with environmental and spatial incidence in the Azores Autonomous Region.

Legal Instrument	Regulatory Decree-Law (National or Azorean Autonomous Law)	Core Subject(s)	Main Goals	Geographic Scope
Regional Strategic Plan for Waste Management (PEGRA – “Plano Estratégico de Gestão dos Resíduos da Região Autónoma dos Açores”)	Regional Decree-Law 10/2008/A	Environmental Conservation and Biodiversity Protection Regional Sustainable Development	Defines a regional strategy for waste management	Region (Achipelago) Island
Regional Strategic Plan for Water Resources Management (PRA – “Plano Regional da Água”)	Regional Decree-Law 19/2003/A	Natural Resources Planning and Management	Defines a regional strategy for Water Resources planning and management	Region (Achipelago) Island
Regional Agricultural Reserve’s Legal Instrument (RAR – “Reserva Agrícola Regional”)	Regional Decree-Law 32/2008/A	Natural Resources Planning and Management	Identifies and establishes protection measures for agricultural soils	Region (Achipelago) Island
Legal Instrument for Agricultural Planning and Cadastre (RJOA – “Regime Jurídico de Ordenamento Agrário”)	Regional Decree-Law 35/2008/A	Natural Resources Planning and Management	Defines the legal instrument for the development of an effective agricultural planning and cadastre	Region (Achipelago) Island
Legal Instrument for Forestry Resources Protection, Planning and Management (RJOF – “Regime Jurídico de Ordenamento Florestal”)	Regional Decree-Law 6/98/A; Regional Regulamentary Decree 13/99/A	Environmental Conservation and Biodiversity Protection Natural Resources Planning and Management	Defines the legal instrument for an effective Forestry Resources Protection, Planning and Management	Region (Achipelago) Island
Emergency and Civil Protection Regional Plan (PREPC – “Plano Regional de Emergência e Protecção Civil”)	Government Council Resolution 26/2007	Civil Protection Natural Hazards Identification and Mitigation	Defines the emergency and civil protection measures to take in order to mitigate the effects of natural catastrophes and further calamity and extreme occurrences	Region (Achipelago) Island
National Ecological Reserve’s Legal Instrument (REN – “Reserva Ecológica Nacional”)	National Decree-Law 166/2008	Environmental Conservation and Biodiversity Protection Natural Resources Planning and Management Natural Hazards Identification and Mitigation	Identifies areas and features with biophysical relevance and and/or natural hazard risk in order to be protected, preserved and managed adequately, to ensure ecosystems integrity and human safety	Region (Achipelago) Island

As core instruments for land planning in the Azores, the PMOT and PEOT have also to integrate, into their land-use classification and planning approaches, region-scaled and island-scaled sectorial policies emanated from Regional and Sectorial plans, both being strategic tools aiming to attribute a spatial dimension to thematic and sectorial policies that are crucial for a Sustainable Development of the archipelago:

- The Azores Master Plan Scheme (PROTA) for land-use strategies definition;
- Economic development: Regional Plan of Tourism (POTRAA), for tourism planning and management policies;
- Environmental conservation and biodiversity protection: Sectorial Plan for the Natura 2000 Network Management (PSRN2000); Regional Plan for the Erradication and Control of Invasive Alien Species in Sensitive Areas (PRECEFIAS); Regional Strategic Plan for Water Resources Management (PRA); Regional Strategic Plan for Waste Management (PEGRA);
- Emergency and Civil Protection Regional Plan (PREPC).

Due to their small dimension (maximum of 745 km² for S. Miguel and minimum of 17 km² for Corvo), the Azorean Islands' terrestrial and coastal environments have to be characterized, planned, managed and assessed using preferentially high spatial resolution imagery (<10m), although medium spatial resolution (<30m) could be useful for some geophysical variables in island-scale mapping (e.g. soil, lithology). Therefore, Sentinel-1 (Synthetic Aperture Radar) and Sentinel-2 (optical) sensors could constitute both the most logical and appropriate GMES Space Component Sentinel Missions' product providers for land-based legal instruments with environmental and spatial incidence in the Azores Autonomous Region (Tab. 3). Nevertheless, due to the mountainous topography and to the high degree of humidity that characterize the Azorean Islands, backscattering intensity and interferometric coherence [van Zyl, 1993; van Zyl et al., 1993; Castel et al., 2002; Danklmayer et al., 2009] are affected when using Synthetic Aperture Radar (SAR) sensors in this type of environments. That's the reason why the Sentinel 1 Mission (high-resolution microwave imaging) products could not represent an effective and fully reliable solution in order to be integrated and implemented into the "GMES Azorean Regional Framework". Consequently, the Sentinel 2 Mission (high-resolution multispectral imaging), which consists of a multispectral imager mission with 13 spectral bands and resolutions of 10, 20 and 60 m; with a swath width of 290 km; constitutes the most adequate, reliable and cost-effective Sentinel Mission in order to support the land-based legal instruments which are currently being applied in this region. Despite the frequent high degree of cloudiness that characterizes the Azores Islands throughout most of the year [Gil et al., 2011], this mission will mitigate the impact of this issue by offering a high repeat cycle of six days at the equator and three days in mid-latitudes in the two-satellite configuration.

"Land cover" refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures. On the other hand "Land use" represents the social and economic purposes and contexts for and within which lands are managed. Land use-land cover (LULC) changes play a major role in the study of global change. LULC and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural hazards [Mas et al., 2004]. These environmental problems are often related to LULC changes. The LULC alterations are generally caused by mismanagement of agricultural, urban, range and forest lands which

lead to severe environmental problems such as landslides, floods etc. Therefore, available data on LULC changes can provide critical input to decision-making of environmental management and planning the future [Prenzel, 2004].

In small islands with very sensitive ecosystems, an accurate LULC mapping and registering of its evolution (change detection and assessment) is mandatory for a more reliable and effective land planning and management. Despite its usefulness at European continental and regional level, Corine Land Cover (CLC) – the European Environment Agency program for LULC multi-temporal mapping and assessment in Europe [Bossard et al., 2000] – has been ineffective to address evolution and change issues regarding European Small Islands/OER LULC. This is due to its too broad geographic scale (1/100,000), its too large minimum spatial unit (25 hectares) comparing to island size, and due to its inadequate legend which prevent an efficient characterization of typical natural and semi-natural LULC units in these territories. Furthermore, the Azores Islands are still geographically not covered by CLC program. At national (Portugal) level, the former National Center of Geographic Information (CNIG) – which is currently the Portuguese Geographic Institute, IGP – started developing, in 1990, a detailed Land Cover Map (COS'90) of mainland Portugal, based on photo-interpretation of high-resolution true-color orthophotomaps [Nunes, 2008]. COS'90 is currently being updated by using orthophotomaps from 2007, through COS'2007 Land Cover Map, which maintains the same main technical requisites and characteristics of COS'90 in order to allow a 17 year (1990 – 2007) LULC change assessment as part of the project [Caetano et al., 2008]. When compared to CLC, although COS'90/COS'2007 are characterized by a more detailed geographic scale (1/25000), a smaller minimum spatial unit (1 hectare) and a legend especially defined to map the existing LULC units in Portugal's mainland, this ambitious LULC mapping project has not been reproduced in the Azores Autonomous Region, not only due to its political autonomy, but also because of the lack of adequate remote sensing data, as well as human and financial resources in this region. Therefore, an archipelago-based and island-scaled LULC mapping program with a higher spatial and temporal resolution than CLC and COS'90/COS'2007; and with an adequate legend focused on biodiversity and natural resources protection and management is needed to address specifically the LULC characterization, evolution and change issues of the Azores islands. Consequently, as shown in Table 3, detailed LULC mapping and change detection (minimum mapping unit smaller equal to 2500 m²) with a specific and adequate legend to Azores Islands and a quarterly update periodic delivery to GMES regional users constitute the core mapping requisites for the Azorean land-based spatial and environmental legal instruments.

The IDEiA (“Infraestrutura de Dados Espaciais dos Açores”) is the Azorean Spatial Data Infrastructure (SDI) currently being developed by the Science, Technology and Telecom's Department (DRCTC – “Direcção Regional de Ciência, Tecnologia e Comunicações”) of the Azorean Regional Government. Its purpose is to allow geographic information on the autonomous region to be searched, viewed and used, through various access points, in the context of the INSPIRE Directive (Directive 2007/2/EC of the European Parliament and of the Council of March 14th 2007 establishing an Infrastructure for Spatial Information in the European Community). This infrastructure intends to widen its scope: firstly to public institutes, to the Azores' municipalities, to regional public companies and to the University of the Azores. In the future, it may broaden its scope in order to comprise all of the entities that use Geographic Information Systems (GIS) in the Azores.

Table 3 – Linking land-based legal instruments with environmental and spatial incidence in the Azores Autonomous Region to GMES Space Component Sentinel-2 Mission derived products.

Earth Observation Product	Critical classes to be mapped	Legal Instruments to be addressed	Minimum Mapping Unit	Minimum Update Frequency	Required ancillary and in-situ data for processing tasks	Processing Techniques to be applied
Land Use / Land Cover (LULC) Map	1 – Urban/ Built up Area; 2 – Bare soil and Landslide Area; 3 – Rocky and Sandy Coastal Area; 4 - Lakes, Ponds and Water Natural Reservoirs; 5 – Pastureland; 6 – Cropland; 7 - Orchards; 8 – Vineyards; 9 - Production Forest Area; 10 – Natural Forest Area; 11 – Natural Scrubland and Shrubland	PROTA PEOT PMOT POTRAA RRAP PSRN2000 PRECEFIAS RJRAMM	2500 m ²	Quarterly	Digital Elevation Model In situ / groundtruth data	<u>Pre-Processing:</u> Atmospheric correction [Hadjimitsis et al., 2010], geometric correction [Sertel et al., 2007]; <u>Processing:</u> object-based classification [Blaschke, 2010], per-pixel classification [Lu and Weng, 2007]; <u>Post-Processing:</u> Accuracy assessment [Foody, 2002]
LULC Change Detection Map	1 - Changed Area 2 - Non-Changed Area	RJAIA RJOF RAR RJOA PEGRA PRA PREPC REN	2500 m ²	Quarterly	In situ / groundtruth data	Digital Change Detection analysis [Singh, 1989]

Due to the scarcity of human, technical and financial resources, the implementation of a cost-effective “GMES Azorean Regional Framework” is mandatory in order to maximize the societal benefits derived from the access to the GMES Space Component Sentinel Mission outcomes described in the Table 3. A “GMES Azorean Regional Framework” integrated within the original IDEiA main framework will constitute a more operational and cost-effective solution because the fundamental aspect of this SDI resides on the ability to make the services of remote sensing and geographic data available for the regional entities (both public and private) and the general public, whenever they need them, free of charge. This policy complies with the full and open access principle suggested by the European Commission [2009] regarding the GMES Space Component Sentinel Mission outcomes, proposing a free and open access data policy through a free of charge licensing and online access scheme, subject to security aspects, aiming to maximise the beneficial use of Sentinel data for the widest range of applications and intending to stimulate the uptake of information based on Earth observation data for end users.

As proposed in Figure 2, the Science, Technology and Telecom’s Department of the Azorean

Regional Government (DRCTC) will constitute the nuclear entity in order to ensure the setup, development, maintenance and cost-effectiveness of the “GMES Azorean Regional Framework”, at three different levels:

- As the Public Regional Authority in Cartography and Geographic Information Technologies;
- As the management entity of the whole IDEiA platform;
- As the entity responsible for processing the raw GMES Space Component data, according to operational needs (Tab. 3), delivering and making it available to IDEiA users.

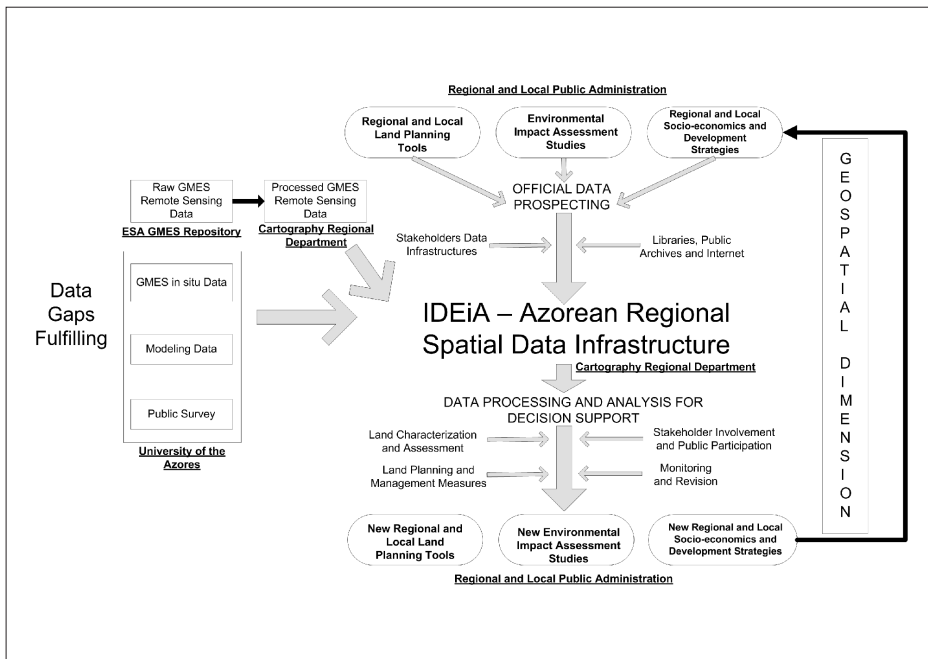


Figure 2 – Spatial Data Infrastructure-based “GMES Azorean Regional Framework”.

Although public regional and municipal entities will be the major contributors of geographic data for the IDEiA platform and the most important users of the “GMES Azorean Regional Framework”, the University of the Azores and its research centers will have to play a fundamental role in this structure’s operational development. In order to ensure the full calibration, assessment and validation of the GMES Sentinel data (especially addressing land and coastal zones at medium and high spatial resolution), multidisciplinary scientific teams from this academic institution will be responsible for setting up, feeding, managing and updating periodically the Regional In-situ GMES infrastructure, with the direct support and contributions of local, regional, national and international R&D centers, NGOs and the Public Administration. Nevertheless, this component shall also be funded and technologically powered and maintained by the Regional Government, in order to strengthen its efficiency and cost-effectiveness.

Conclusions

1 - The European Outermost Regions (most of them being small islands) face several obstacles to full development (remoteness, insularity, terrain, climate, economic dependence and narrow range of the goods they produce) which have been mitigated by European Union cohesion policies. Nevertheless, serious environmental issues such as climate change, environmental degradation, loss of biodiversity and proliferation of IAS have to be directly and especially addressed by using the most reliable scientific information and the most advanced technologies.

2 - By allowing repeated, consistent and reliable assessment and monitoring of the environment, remote sensing can be assumed as a cost-effective supportive tool for environmental policy development in these regions.

3 - The GMES programme plays a vital role in monitoring the sea, land and atmospheric environment, aiming to promote a better understanding of the European and global environments as a basis for policy. An important goal of this programme is creating opportunities for increased private sector usage of information sources which also triggers partnerships between the research and the business community. The GMES Space Component comprises 6 series of Earth observation Sentinel missions that will provide – at no cost for users – high, medium and low spatial resolution data for land, coastal, marine and atmospheric assessment.

4 - Sixteen land-based spatial and environmental legal instruments are currently being applied and developed in the Azores Autonomous Region. They can be divided and classified into five core areas: (1) land planning and management; (2) natural resources management; (3) sustainable economic development; (4) environmental conservation and biodiversity protection; (5) emergency and civil protection. All of them require high and medium spatial resolution data in order to deliver accurate and reliable outputs at special zones (basin and lake, coastal zone, protected areas), at municipal and island scales. Therefore, due to the geographic and geophysical specificities of the Azores Islands, regarding land and coastal assessment, high and medium spatial resolution's GMES Space Component Sentinel-2 mission products could be especially relevant and cost-effective.

5 - Land-use/Land-cover (LULC) cartography and change assessment are the most frequent, nuclear and strategic mapping needs for the development and assessment of legal instruments in the Azores. Pan-european mapping programmes such as Corine Land Cover (CLC) have been ineffective to address Outermost Regions' environmental and land management issues, because of their broad geographic scale (1/100,000), their low spatial resolution (comparing to island size) and their inadequate classification scheme (unable to well characterize LULC units in those territories). At national level (Portugal), both medium-resolution LULC mapping programs COS'90 and COS'2007 have not been implemented in the Autonomous Regions due to political reasons derived from the lack of human, technical and financial resources. Therefore, the use and processing of Sentinel-2 satellite data will be able to address and fulfill this relevant information gap at regional level, by providing accurate (exhaustive and specific legend), detailed (minimum mapping unit of 2500 m²) and frequent (quarterly) LULC cartography and change detection assessment.

6 - A "GMES Azorean Regional Framework" integrated within the main original Regional Spatial Data Infrastructure (IDEiA) framework will constitute a more operational and cost-effective solution. The Science, Technology and Telecom's Department of the Azorean

Regional Government (DRCTC) will constitute the nuclear entity in order to ensure the setup, development, maintenance and cost-effectiveness of this infrastructure. The University of the Azores and its research centers will be responsible for setting up, feeding, managing and updating periodically the Regional In-situ GMES infrastructure, with the direct support and contributions of local, regional, national and international R&D centers, NGOs and the Public Administration.

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